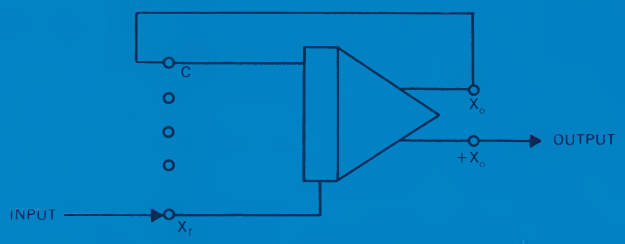
TYPE 19-400 SERIES
DYNAMIC RESPONSE FUNCTIONS

CEC

DEVAR-KINETICS DIVISION



CONSOLIDATED ELECTRODYNAMICS / A SUBSIDIARY OF BELL & HOWELL

TYPE 19-400 SERIES
DYNAMIC RESPONSE
FUNCTIONS

GENERAL DESCRIPTION

High-performance time functions for analog computer and control systems are supplied by CEC/Devar 19-400 Series Dynamic Response Function Modules (color coded blue). Designed for use with other CEC function modules to give system designers a greater scope of performance, function, and convenience than ever before obtainable, the 19-400 Series functions also may be used with instrumentation supplied by others. Function modules in the series are:

Type 19-401 SAMPLE AND HOLD
Type 19-402 INTEGRATOR
Type 19-403 PROPORTIONAL PLUS RESET
Type 19-404 FIRST ORDER LAG
Type 19-405 DIFFERENTIATOR

Each function in the series employs the same basic module. Variations are achieved by the addition of appropriate sub-modules to the function module's terminal face. Each basic module contains:

High impedance operational amplifier
Low leakage computing capacitor
Initial condition (tracking) network and relay
Inverting amplifier

High-performance characteristics are shown graphically with comparative values also shown for typical industrial process control equipment previously obtainable.

To facilitate the design of systems using the dynamic response functions with other CEC function modules, inputs and outputs feed between modules without intermediate conditioning devices. Nominal inputs and outputs are ± 10 volts. Other input and output values can be scaled externally by encapsulated coefficient resistors fastened to the function-module terminals.

Long life in continuous service, the strictest requirement placed on process control instrumentation, is assured by screw-type terminals and by encapsulation of circuits. Corrosive atmospheres, vibration, or shock will not damage components – each module's "as new" capability is sealed in. Furthermore, potentially unreliable zero- and gain-trimming potentiometers, selector switches, and electrolytic capacitors are avoided. Instead, high-gain, low-drift amplifiers are used in conjunction with .01% computing resistors. Since modules are factory repairable, maintenance is eliminated. System repair, if necessary, is done simply by module replacement.

Dimensions of all CEC/Devar function modules are related for flexibility of system design – and because each function may be combined with over thirty others, their use in the creation of simple or complex systems is virtually unlimited.

While demand increases for modern control systems of greater sophistication, requirements also stipulate that a simple straightforward approach be used to make systems practical for plant use. Only by applying basic analog computer techniques using functions supplied individually in encapsulated modules, can these divergent requirements be met.

PRINCIPLE OF OPERATION

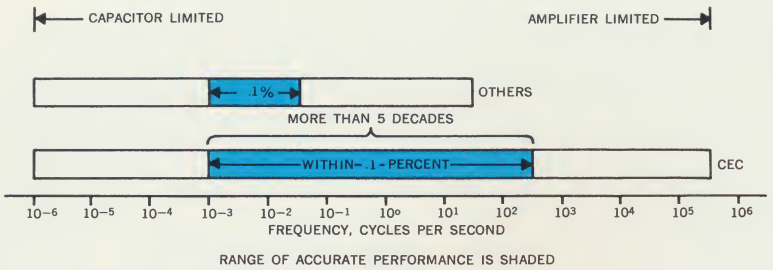
Dynamic response functions employ an operational amplifier (1) with very high input impedance (see schematic diagram). Conventional analog computer techniques are applied to obtain a variety of dynamic response functions. The capacitor (C) is a low leakage, 3 mfd capacitor which may be used either as as input impedance element or as a feedback element. External computing impedance elements connect at $X_1 - e_1$, $X_2 - e_2$, or $X_0 - e_3$ to form additional input or feedback elements.

Resistors R_1 and R_2 are of equal value so that in the TRACK mode, amplifier (1) inverts the TRACK voltage X_T, and $X_o = X_T$.

In the integrator connection, this rapidly charges capacitor (C) to the desired initial voltage. It also provides "bumpless" transfer in controller applications.

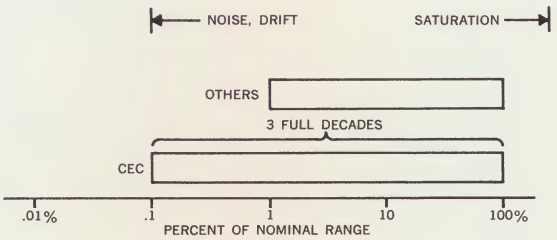
Resistors R_3 and R_4 also are equal and amplifier (2) is wired permanently as a unity gain inverter. Positive and negative outputs, thus, are made available in any application.

An internal relay connects the TRACK (initial condition) mode when energized. The relay may be controlled by manual switch, or by the output from another CEC/Devar module.



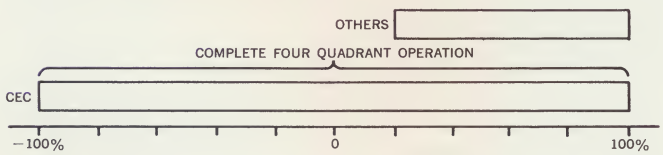
SAMPLE AND HOLD

When used without accessory coefficients, the basic dynamic response module is designated Type 19-401 Sample and Hold. Drift rate of the function at a given level is less than .2% in the first hour and decreases with time at a given level.



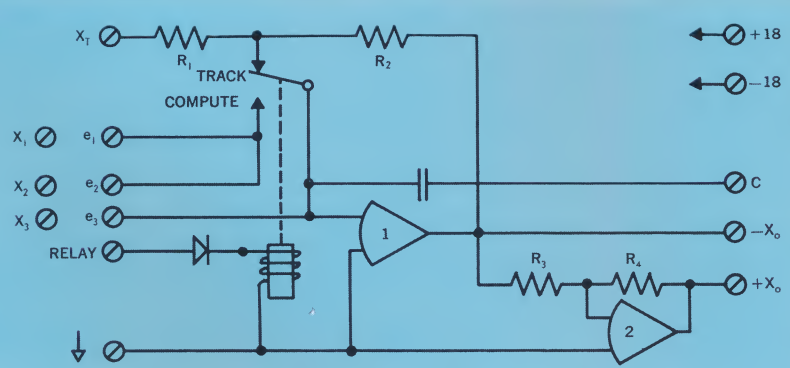
INTEGRATOR

Inverse Time Selector Elements (÷) are added to the basic function module to form the Type 19-402 Integrator. The desired time elements are specified by the user (see table). Zero frequency gain typically is greater than 10,000.



PROPORTIONAL PLUS RESET

Inverse Time Selector Elements (÷) and Capacitor (C) are included to form the Type 19-403 Proportional Plus Reset function. Proportional band is 100% and reset rate is set as listed in the Coefficient Element Table. Proportional response can be turned off by disconnecting (C).



DYNAMIC RESPONSE FUNCTIONS
SCHEMATIC DIAGRAM

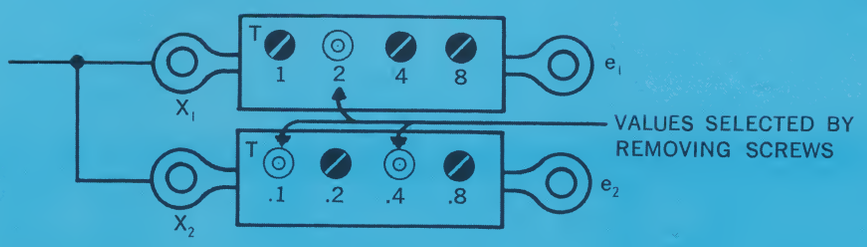
FIRST ORDER LAG (FILTER)

By adding Time Selector Elements a Type 19-404 First Order Lag function is formed. The user specifies desired Time Selector Elements from those listed in the Coefficient Element Table. To change the filter time constant without changing the low frequency gain, it is necessary to change both time elements.

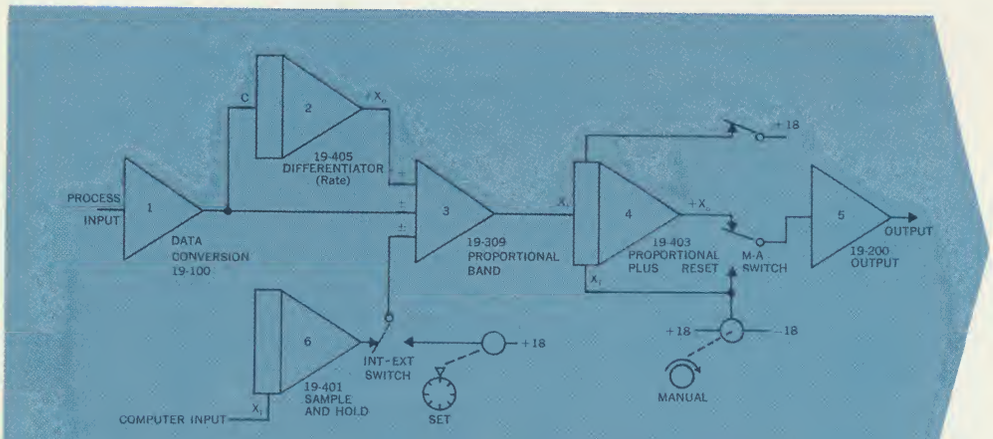
DIFFERENTIATOR (RATE)

The Type 19-405 Differentiator responds to rate of change only and the module's output is combined with the proportional signal, when appropriate, in the succeeding function module. The user specifies the Time Selector Elements desired (see table). Capacitor (C) sets the high frequency gain at times 10.

RATE TIME SELECTOR SUB MODULE



RATE TIME OF 2.5 MINUTES ILLUSTRATED



TYPICAL FUNCTION MODULE SYSTEM (PROCESS CONTROLLER)

SERIES 19-000 COEFFICIENT ELEMENT TABLE

SYMBOL	FUNCTION	COEFFICIENT	TOLERANCE
1/T	Inverse Time Selector	.01, .02, .04, .08 repeats/min.	30%
1/T	Inverse Time Selector	1, 2, 4, 8 repeats/min.	5%
1/T	Inverse Time Selector	10, 20, 40, 80 repeats/min.	5%
1/T	Inverse Time Selector	100, 200, 400, 800 repeats/min.	5%
T	Time Selector	.001, .002, .004, .008 minutes	5%
T	Time Selector	.01, .02, .04, .08 minutes	5%
T	Time Selector	.1, .2, .4, .8 minutes	5%
T	Time Selector	1, 2, 4, 8 minutes	10%
P.B.	Proportional Band Selector	2, 4, 8, 16 percent	5%
P.B.	Proportional Band Selector	20, 40, 80, 160 percent	5%
C	Capacitor	.3 microfarads	10%
C	Capacitor	3.0 microfarads	10%

TYPICAL FUNCTION MODULE SYSTEM (PROCESS CONTROLLER)

INPUT SIGNAL CONVERSION (1)

One of the Type 19-100 Series Data Conversion Modules converts virtually any form of input signal: milliamperes, microamperes, volts, millivolts, as well as time and frequency modulation. See other CEC/DEVAR function module bulletins.

DIFFERENTIATOR (RATE) (2)

The Type 19-405 Differentiator (Rate) responds only to the process signal. This optional function precedes reset for start-up without over-shoot.

PROPORTIONAL BAND (3)

This module adds or subtracts up to four inputs. Either + or – response to each input. The Type 19-309 Proportional Band Function includes two Proportional Band Selectors (P.B.) which permit the selection of any even number from 2 to 330 per cent. It also is equipped with four unity coefficient elements (a). The module itself is identical to the Type 19-301 Adder-Subtractor.

PROPORTIONAL PLUS RESET (4)

This Type 19-403 Proportional Plus Reset module is optional and is omitted when the reset function is not required. The proportional response can be cut out if desired for "Floating" control action. Tracking accuracy is .1%, and "bumpless" transfer does not depend on the input deviation.

OUTPUT SIGNAL CONVERSION (5)

One of the Type 19-200 Series Output Modules is employed to provide the desired output range, power level, or type of modulation.

SAMPLE AND HOLD (6)

Digital computer outputs are sampled periodically and stored by means of a Type 19-401 Sample and Hold Module. After a short time at any given level, typical drift rate is less than .1% per hour.

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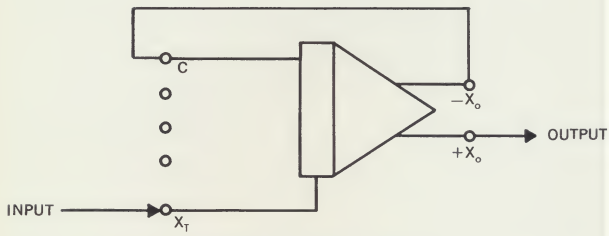
Bulletin 19400/ November, 1964

SAMPLE AND HOLD

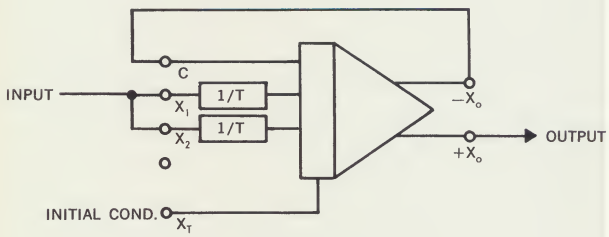
When used without accessory coefficients, the basic dynamic response module is designated Type 19-401 Sample and Hold. Drift rate of the function at a given level is less than .2% in the first hour and decreases with time at a given level.



SAMPLE AND HOLD
TYPE 19-401

INTEGRATOR

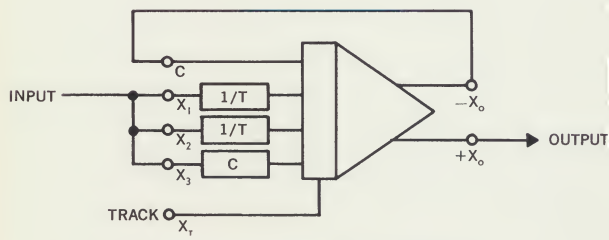
Inverse Time Selector Elements ($\frac{+}{-}$) are added to the basic function module to form the Type 19-402 Integrator. The desired time elements are specified by the user (see table). Zero frequency gain typically is greater than 10,000.



INTEGRATOR
TYPE 19-407

PROPORTIONAL PLUS RESET

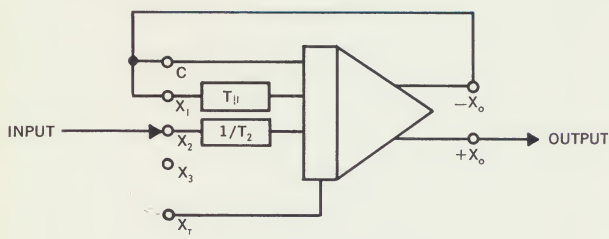
Inverse Time Selector Elements ($\frac{+}{-}$) and Capacitor (C) are included to form the Type 19-403 Proportional Plus Reset function. Proportional band is 100% and reset rate is set as listed in the Coefficient Element Table. Proportional response can be turned off by disconnecting (C).



PROPORTIONAL PLUS RESET
TYPE 19-403

FIRST ORDER LAG (FILTER)

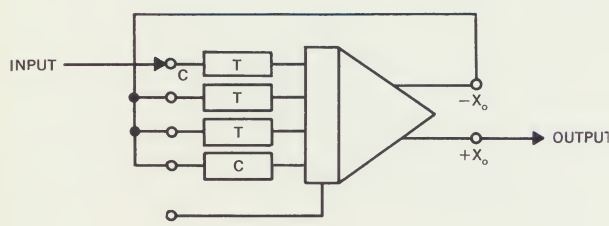
By adding Time Selector Elements a Type 19-404 First Order Lag function is formed. The user specifies desired Time Selector Elements from those listed in the Coefficient Element Table. To change the filter time constant without changing the low frequency gain, it is necessary to change both time elements.



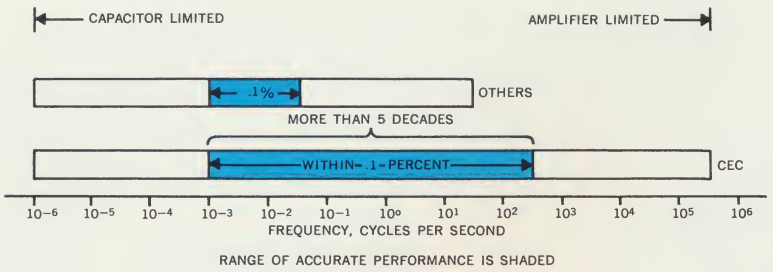
FIRST ORDER LAG-(FILTER)
TYPE 19-404

DIFFERENTIATOR (RATE)

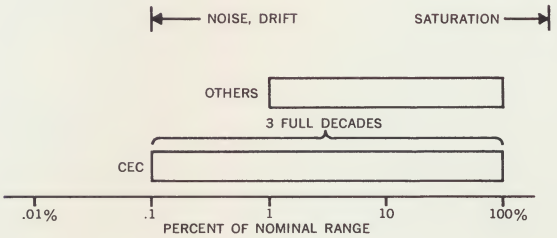
The Type 19-405 Differentiator responds to rate of change only and the module's output is combined with the proportional signal, when appropriate, in the succeeding function module. The user specifies the Time Selector Elements desired (see table). Capacitor (C) sets the high frequency gain at times 10.

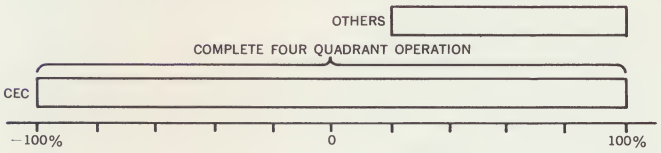


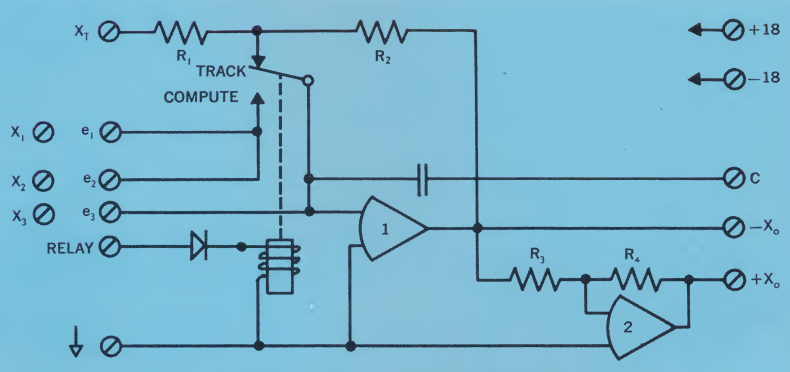
DIFFERENTIATOR (RATE)
TYPE 19-405



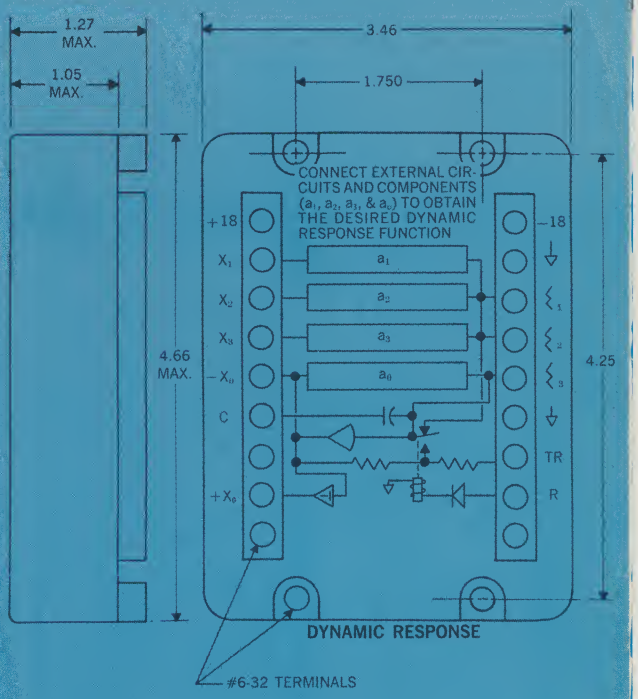
RANGE OF ACCURATE PERFORMANCE IS SHADED







DYNAMIC RESPONSE FUNCTIONS
SCHEMATIC DIAGRAM



BASIC FUNCTION MODULE SPECIFICATIONS

TYPE 19-400 SERIES DYNAMIC RESPONSE FUNCTIONS

HIGH IMPEDANCE AMPLIFIER

Input current offset: less than 10^{-11} amperes.
Input voltage offset: less than 10^{-2} volts, 3×10^{-3} typically.
Input resistance: greater than 10^{12} ohms
Supply effect: less than 4 millivolts referred to summing junction per 1% supply change.
Bandwidth: approximately 250 kc (3 db) at unity gain.
Open loop voltage gain: 10,000 minimum
Output noise: less than 10 millivolts p-p.
Nominal output range: ±10 volts d-c.
Maximum output range: ±14 volts d-c
Maximum load current: ±20 milliamperes, max.

INVERTING AMPLIFIER

Offset voltage at output: 3×10^{-3} volts, typical, 10^{-2} max.
Gain: −1,000, tolerance .1%
Output range, load, etc.: same as above.

COMPUTING CAPACITOR (C) (INTERNAL CAPACITOR)

Value: 3 mfd ±10%
Insulation resistance: more than 10^6 megohms x microfarads at 70° F, 3×10^5 at 120° F. Insulation increases with time at a fixed voltage level.

TRACK RELAY

Pull in: 11 volts max.
Coil resistance: 5,000 ohms
Response time: 15 milliseconds

POWER REQUIRED

+18 volts at 14 ma
−18 volts at 14 ma
} plus output load